

Effect of LEO Cycling on 125 Ah Advanced Design IPV Nickel-Hydrogen Battery Cells

John J. Smithrick
Lewis Research Center
Cleveland, Ohio

and

Stephen W. Hall
Naval Weapons Support Center
Crane, Indiana

Prepared for the
25th Intersociety Energy Conversion Engineering Conference
cosponsored by the AIChE, SAE, ACS, AIAA, ASME, and IEEE
Reno, Nevada, August 12-17, 1990



(NASA-TM-103128) EFFECT OF LEO CYCLING ON
125 AH ADVANCED DESIGN IPV NICKEL-HYDROGEN
BATTERY CELLS (NASA) B D CSCL 10A

N90-21808

Unclass

63/20 0278657

EFFECT OF LEO CYCLING ON 125 Ahr ADVANCED DESIGN IPV

NICKEL-HYDROGEN BATTERY CELLS

John J. Smithrick
NASA Lewis Research Center
Cleveland, Ohio 44135

and

Stephen W. Hall
Naval Weapons Support Center
Crane, Indiana 47522

ABSTRACT

An advanced 125 Ahr individual pressure vessel (IPV) nickel-hydrogen cell was designed. The primary function of the advanced cell, is to store and deliver energy for long-term, low-earth-orbit (LEO) spacecraft missions. The new features of this design are: (1) use of 26 percent rather than 31 percent potassium hydroxide (KOH) electrolyte, (2) use of a patented catalyzed wall wick, (3) use of serrated-edge separators to facilitate gaseous oxygen and hydrogen flow within the cell, while still maintaining physical contact with the wall wick for electrolyte management, and (4) use of a floating rather than a fixed stack (state-of-the-art) to accommodate nickel electrode expansion due to charge/discharge cycling. The significant improvements resulting from these innovations are extended cycle life; enhanced thermal, electrolyte, and oxygen management; and accommodation of nickel electrode expansion. Six 125 Ahr flight cells based on this design were fabricated by Eagle-Picher. Three of the cells contain all of the advanced features (test cells) and three are the same as the test cells except they do not have catalyst on the wall wick (control cells). All six cells are in the process of being evaluated in a LEO cycle life test at the Naval Weapons Support Center, Crane, IN, under a NASA Lewis contract. The cells have accumulated about 4700 LEO cycles (60 percent DOD 10 °C). There have been no cell failures, the catalyzed wall wick cells however, are performing better.

INTRODUCTION

As part of an overall effort to advance the technology of nickel-hydrogen batteries for use in a space power system an advanced design for an IPV battery cell was conceived. The intent of this effort was to improve cycle life at moderate to deep-depths-of-discharge (40 to 80 percent). The approach was to review IPV nickel-hydrogen cell designs and results of cycle life test conducted in-house and by others to identify areas where improvements could result in a longer cycle life.²⁻⁸ Design philosophies were developed relative to oxygen and electrolyte management requirements.⁹ The feasibility of the advanced design was demonstrated using 6 Ahr boiler plate cells and 31 percent KOH electrolyte.¹⁰ Recently, a major

LEO cycle life improvement using state-of-art design boiler plate cells, 26 percent KOH and an accelerated cycle regime was achieved under a NASA Lewis contract with Hughes.¹¹⁻¹³

The purpose of this experiment is to validate the advanced cell using flight hardware containing 26 percent KOH and compare cells containing the catalyzed wall wick to cells without it. Six 125 Ahr capacity flight cells based on the advanced design were fabricated by Eagle-Picher Joplin, MO. Three of the cells contain all of the advanced features (test cells) and three are the same as the test cells except they do not have catalyst on the wall wick (control cells). They are undergoing real time LEO cycle life testing at the Naval Weapons Support Center (NWSC), Crane, IN under a NASA Lewis contract.

Results of storage, characterization, and cycle life testing of advanced cells with and without the catalyzed wall wick will be reported.

EXPERIMENTAL

Test Facility

The facility is capable of testing 45 battery packs with maximum of 10 cells electrically connected in series per pack. Each pack has its own charge and discharge power supply which is controlled by a computer that is programmed to satisfy the particular test requirements. During testing each pack is scanned every 2.4 min to compare data such as voltage, temperature and pressure with programmed limits. If a parameter is out of limit an alarm will be initiated and a message will be typed out identifying the cell and parameter. The data is recorded on a 132 MB disc drive and if requested can be obtained in report form. The cell temperature during a test is controlled by a recirculating cooler that circulates a solution of water and ethylene glycol through a cooling plate.

Cell Description

The six cells are 125 Ahr capacity advanced flight IPV nickel-hydrogen cells. They were fabricated by Eagle Picher, Joplin, MO according to NASA Lewis Research Center specifications using nickel electrodes fabricated at Eagle Picher, Colorado

Springs, CO and were impregnated with active material by the alcoholic Pickett process.¹⁴ Three of the cells (test cells) contain all of the advanced design features as described in reference 1. The other three cells (control cells) are the same as the test cells except they do not have catalyst on the wall wick. All six cells contain 26 rather than 31 percent KOH electrolyte.

The test cell design is illustrated in figure 1. The new features of this design which are not incorporated in the state-of-the-art Air Force/Hughes or Comsat/Intelsat cells are: (1) use of 26 percent rather than 31 percent KOH electrolyte which improves cycle life,¹¹⁻¹³ (2) use of a catalyzed wall wick located on the inside surface of the pressure vessel wall. It is used to chemically recombine the oxygen generated at the end of charge and on overcharge with hydrogen to form water. State-of-the-art nickel hydrogen cells recombine the oxygen on the catalyzed hydrogen electrode surface in the stack. The catalyzed wall wick should improve oxygen and thermal management,¹⁵ (3) the use of serrated edge separators to facilitate gaseous oxygen and hydrogen flow within the cell, while still maintaining physical contact with the wall wick for electrolyte management, and (4) use of a floating rather than a fixed stack (SOA) to accommodate nickel electrode expansion due to charge/discharge cycling. This is accomplished by use of Belleville disc springs located at each end of the stack. The significant improvements resulting from these innovations are extended cycle life, enhanced oxygen, thermal and electrolyte management, and accommodation of some of the nickel electrode expansion.

Measurements and Procedures

The quantities measured every 2.4 min for each cell during charge and discharge and their accuracies are: current (± 2.0 percent), voltage (± 0.001 percent), pressure (± 1 percent), and temperature (± 1 percent). Charge and discharge ampere-hour capacities were calculated from current and time. The charge to discharge ratio (ampere-hours into cell on charge to ampere-hours out on discharge) are calculated from the charge and discharge ampere-hour capacities. Cell charge and discharge currents are calculated from measured voltage across a shunt, using an integrating digital voltmeter. Cell voltage is measured, also using an integrating digital voltmeter. Cell pressure is measured using a strain gauge located on the cell dome. The temperature is measured using a thermistor located on the center of the pressure vessel dome. The thermistor is mounted using a heat sink compound to insure good thermal contact.

After completion of activation testing by the manufacturer the precharge hydrogen pressure was set to 0 psig (14.5 psia) with the nickel electrodes in the fully discharged state. After completion of the acceptance testing the cells were discharged at the C/10 rate (12.5 A) to 0.1 V or less and the terminals were shorted. The cells were shipped to NWSC, Crane, where they were stored open circuit, discharge, 0 °C for 52 days.

After storage the discharge ampere-hour capacity acceptance test was repeated. The capacity was measured after charging the cells at the C/2 rate (62.5 A) for 2 hr, then C/10 for 6 hr, followed by a 0.5 hr open circuit stand. The discharge capacity was measured to 1.0 V for each of the following rates: C/2, C, 1.4C, and 2C.

Prior to under going cycle life testing the capacity retention after a 72 hr open circuit stand (10 °C) was measured for all cells. For the cycle life test the cells were connected electrically in series to form a six cell pack. The cycle regime is a 90 min LEO orbit consisting of a 54 min charge at a constant 0.69C rate (87 A) followed by 36 min discharge at C rate (125 A). The charge to discharge ratio was 1.04. The depth-of-discharge was 60 percent of name plate capacity (125 Ahr). During the cycle life test the cooling plate temperature was maintained at 10 ± 2 °C. Cell failure for this test was defined to occur when the discharge voltage degrades to 1.0 V during the course of the 36 min discharge.

RESULTS AND DISCUSSION

Cell Performance

For a representative 125 Ahr advanced catalyzed wall wick nickel-hydrogen flight battery cell the voltage and pressure during charge and discharge are shown in figure 2 (beginning of life). The discharge rate was 0.69C (87 A) and the temperature was a nominal 10 °C. The mid discharge voltage was 1.248 V. The pressure, as expected varies linearly with the state-of-charge. It should be noted, however, that the pressure could increase with charge/discharge cycling causing a shift in the state-of-charge curve.

The effect of discharge rate on ampere-hour capacity for a representative cell of each type is shown in figure 3. The capacity decreased slightly (1 percent) over the range of C/2 to 1.4C, (175 A) after which point it decreases rapidly. In a nickel-hydrogen cell the gaseous hydrogen comes into contact with the nickel electrodes resulting in a capacity loss due to self discharge. The capacity retention of the cells after a 72 hr open circuit stand at 10 °C is shown in figure 4. The data shows that there is no significant difference in capacity retention between the catalyzed and noncatalyzed wall wick cells. For the catalyzed wall wick cells on the average it is 84 percent and for the noncatalyzed wall wick cells it is 85 percent.

Storage Test

The effect of storage (52 days, discharged, open circuit, 0 °C) on the capacity of the six, 125 Ahr flight IPV nickel-hydrogen cells is summarized in figure 5. The spread in the data show that there is more variability in capacity loss between similar cells than there is between the test groups indicating there is no capacity loss between the two groups due to the 52 day storage.

Actually there was a slight average increase in capacity for both the catalyzed and noncatalyzed wall wick cells after the 52 day storage.

Cycle Test

The average end of discharge voltage for the catalyzed and noncatalyzed 125 Ahr IPV nickel-hydrogen flight cells is shown in figure 6. After about 4700 cycles no cells have failed and the voltage for the catalyzed wall wick cells is relatively stable. The voltage for the noncatalyzed wall wick cells show a degradation up to about cycle 4200, followed by an increase in voltage to a stabilized value of about 45 mV lower than the noncatalyzed wall wick cells. The influence of cycling on the end of discharge voltage for the individual catalyzed wall wick cells is shown in figure 7 and for the individual noncatalyzed cells in figure 8.

The influence of cycling on the end-of-charge pressure for the catalyzed wall wick cells is shown in figure 9. No pressure data for cell two is available because cell two had a bad strain gauge. For the other two cells the pressure increased relatively rapidly up to about cycle 1400. The average pressure increase at cycle 1400 is about 11 percent higher than at the beginning of cycling.

The influence of cycling on the end of charge pressure for the noncatalyzed wall wick cells is shown in figure 10. The pressure increased for the three cells up to about cycle 2000 then decreased. The average pressure increase at cycle 2000 is about 9 percent higher than at the beginning of cycling.

The cycle life testing of these cells will continue until failure. A post cycle teardown and failure analysis will be conducted to evaluate the cause for cell failure. This information will be used to effect further improvements.

CONCLUDING REMARKS

Validation testing of NASA Lewis 125 Ahr advanced design IPV nickel-hydrogen flight cells is being conducted at NWSC, Crane, under a NASA Lewis contract. This consists of characterization, storage and cycle life testing. There was no capacity degradation after 52 days of storage with the cells in the discharged state, on open circuit, 0 °C, and a hydrogen pressure 14.5 psi. The cells have been cycled for about 4700 LEO cycles at 60 percent DOD with no cell failures. The end of discharge voltage performance is better for the catalyzed wall wick cells. These early initial results indicate the advance design may be an improvement.

REFERENCES

1. Smithrick, J.J.; Manzo, M.A.; and Gonzalez-Sanabria, O.: Advanced Designs for IPV Nickel-Hydrogen Cells. Advanced Energy

Systems - Their Role in Our Future (19th IECEC), Vol. 1, ANS, New York, 1984, pp. 631-635.

2. Adler, E., et al.: Nickel-Hydrogen Battery Advanced Development Program. AFWAL-TR-80-2044, Hughes Aircraft Company, 1980 (Avail. NTIS, AD-B049914L).
3. Warnock, D.H.: Life Test of 50 AH NiH₂ Battery. The 1981 Goddard Space Flight Center Battery Workshop, G. Halpert, ed., NASA CP-2217, 1982, pp. 487-500.
4. Smithrick, J.J.: Cycle Life Test and Failure Model of Nickel-Hydrogen Cells. Energy for the Marketplace (18th IECEC), Vol. 4, AIChE, 1983, pp. 1535-1542.
5. Fritts, D.H.: Testing the Mechanical Characteristics of Sintered Nickel Battery Plaque and Their Relationship to Nickel Electrode Performance. J. Power Sources, vol. 6, Apr. 1981, pp. 171-184.
6. Pickett, D.F., et al.: Establishment of Parameters for Production of Long Life Nickel Oxide Electrodes for Nickel-Hydrogen Cells. Energy to the 21st Century (15th IECEC), Vol. 3, AIAA, New York, 1980, pp. 1918-1924.
7. Mueller, V.C.: Failure Analysis of Nickel-Hydrogen Cell Subjected to Simulated Low Earth Orbit Cycling. The 1983 Goddard Space Flight Center Battery Workshop, D. Baer and G.W. Morrow, eds., NASA CP-2331, 1983, pp. 523-538.
8. Abbey, K.M.; and Britton, D.L.: Electrolyte Management in Porous Battery Components-Static Measurements. NASA TM-83073, 1982.
9. Thaller, L.H.; Manzo, M.A.; Sanabria-Gonzalez, O.D.: Design Principles for Nickel-Hydrogen Cells and Batteries. Energy for the Twenty-first Century (20th IECEC), Vol. 1, SAE, 1984, pp. 145-150.
10. Smithrick, J.J.: Initial Performance of Advanced Designs for IPV Nickel-Hydrogen Cells. Power Sources 11, L.J. Pearce, ed., International Power Sources Symposium Committee, Leatherhead, England, 1986, pp. 215-226.
11. Lim, H.S.; and Verzwylt, S.A.: KOH Concentration Effect on Cycle Life of Nickel-Hydrogen Cells. III. Cycle Life Test. J. Power Sources, vol. 22, Mar.-Apr. 1988, pp. 213-220.
12. Lim, H.S.; and Verzwylt, S.A.: KOH Concentration Effect on the Cycle Life of Nickel-Hydrogen Cells. IV. Results of Failure Analysis. J. Power Sources, 1990, to be published.

13. Lim, H.S.; and Verzwylt, S.A.: Electrochemical Behavior of Heavily Cycled Nickel Electrodes in Na-H₂ Cells Containing Electrolytes of Various KOH Concentrations. Presented at the 176th Meeting of the Electrochemical Society, Hollywood, FL, Oct. 15-20, 1989 (in press, 1990).
14. Pickett, D.F.: Preparation of Nickel Electrodes. U.S. Patent 3,827,911, Aug. 1974.
15. Sanabria-Gonzalez, O.D.: Effect of NASA Advanced Designs on Thermal Behavior of Ni-H₂ Cells. Proceedings of the 23rd IECEC, Vol. 2, ASME, New York, 1988, pp. 453-456.

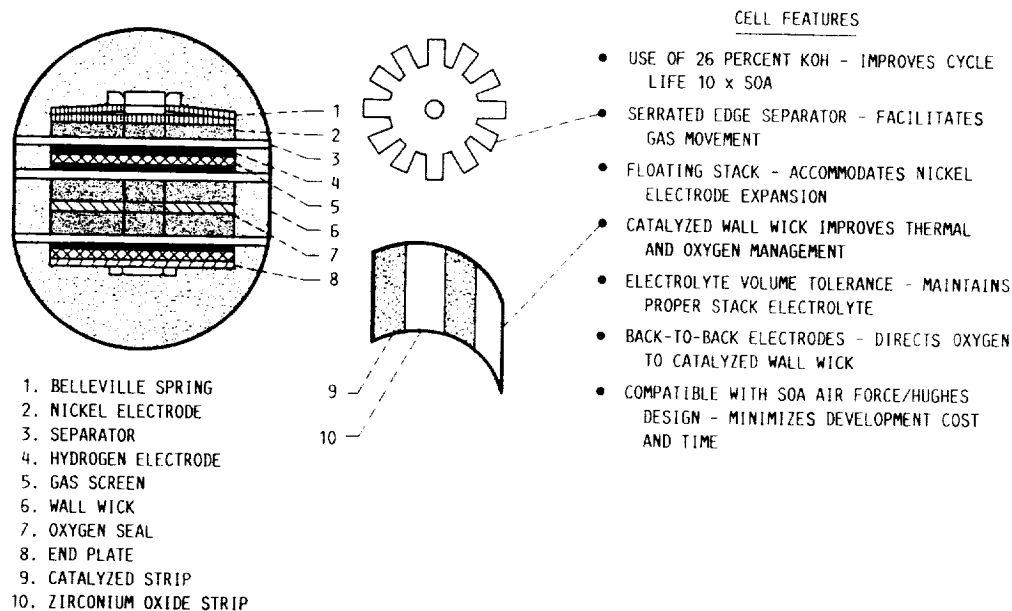


FIGURE 1. - NASA ADVANCED DESIGN IPV NICKEL-HYDROGEN CELL-CATALYZED WALL WICK.

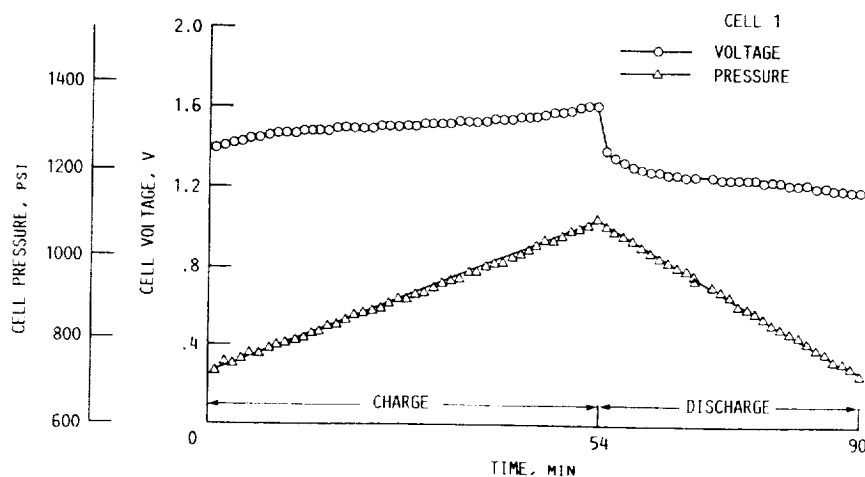


FIGURE 2. - CELL VOLTAGE AND PRESSURE DURING CHARGE AND DISCHARGE FOR A REPRESENTATIVE 125 A-hr ADVANCED CATALYZED WALL WICK IPV Ni-H₂ FLIGHT BATTERY.

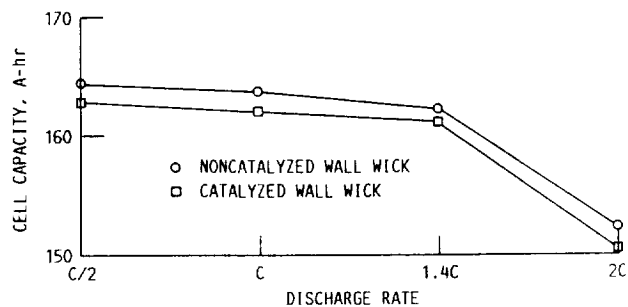


FIGURE 3. - COMPARISON OF EAGLE-PICHER 125 A-hr Ni-H₂ CELLS CATALYZED AND NONCATALYZED WALL WICK.

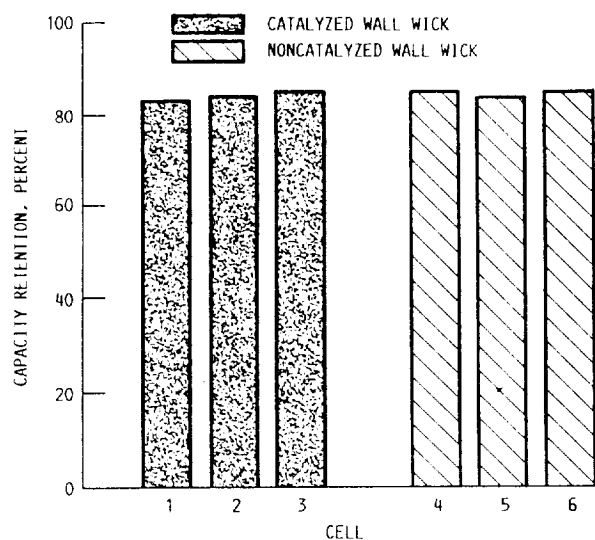


FIGURE 4. - CAPACITY RETENTION OF 125 A-hr EAGLE-PICHER ADVANCED IPV Ni-H₂ FLIGHT CELLS AFTER 72 HOUR OPEN CIRCUIT STAND.

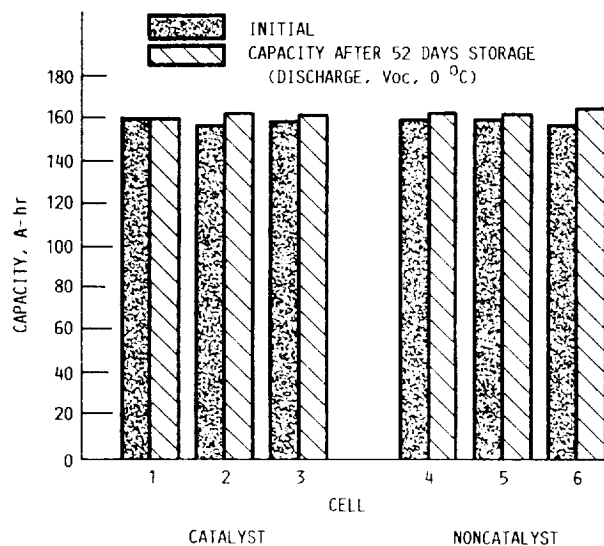


FIGURE 5. - EFFECT OF STORAGE ON CAPACITY OF 125 A-hr EAGLE-PICHER ADVANCED FLIGHT IPV Ni-H₂ CELLS, CATALYZED AND NONCATALYZED WALL WICK, 26 PERCENT KOH.

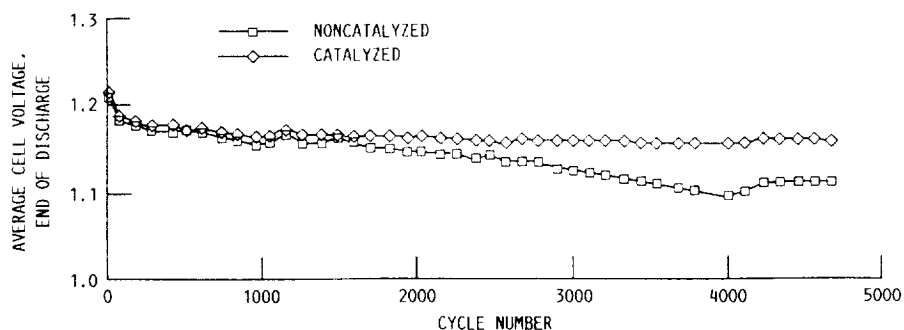


FIGURE 6. - EFFECT OF LEO CYCLING ON 125 A-hr NASA ADVANCED IPV Ni-H₂ CELLS MANUFACTURED BY EAGLE-PICHER - 26 PERCENT KOH, 60 PERCENT DOD, 10 °C.

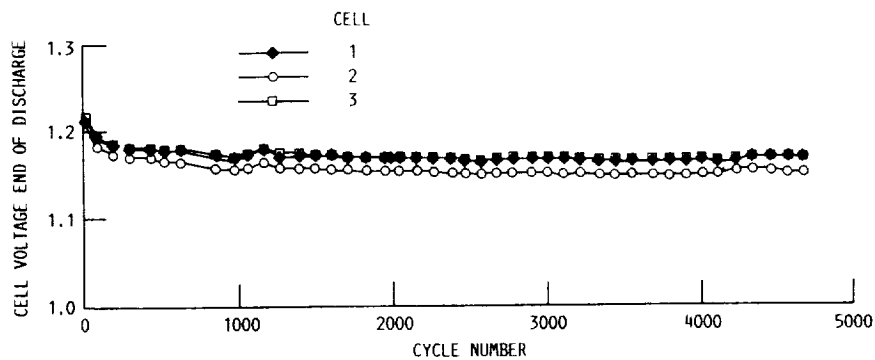


FIGURE 7. - EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED CATALYZED WALL WICK IPV Ni-H_2 CELLS MANUFACTURED BY EAGLE-PICHER - 26 PERCENT KOH, 60 PERCENT DOD, 10°C .

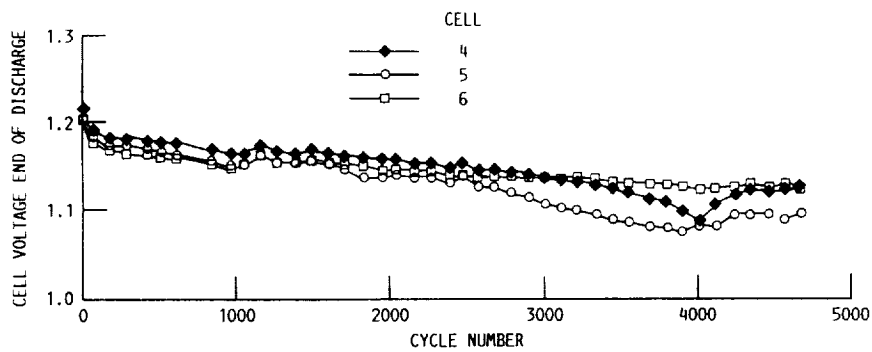


FIGURE 8. - EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED NONCATALYZED WALL WICK IPV Ni-H_2 CELLS MANUFACTURED BY EAGLE-PICHER - 26 PERCENT KOH, 60 PERCENT DOD, 10°C .

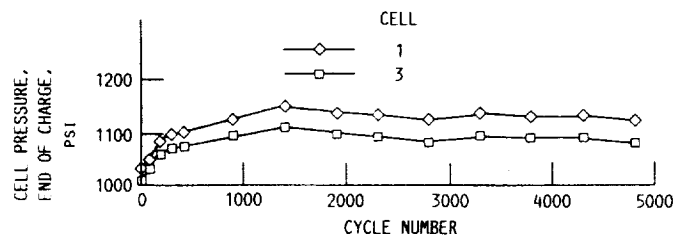


FIGURE 9. - EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED CATALYZED WALL WICK IPV Ni-H_2 CELLS MANUFACTURED BY EAGLE-PICHER - 26 PERCENT KOH, 60 PERCENT DOD, 10°C .

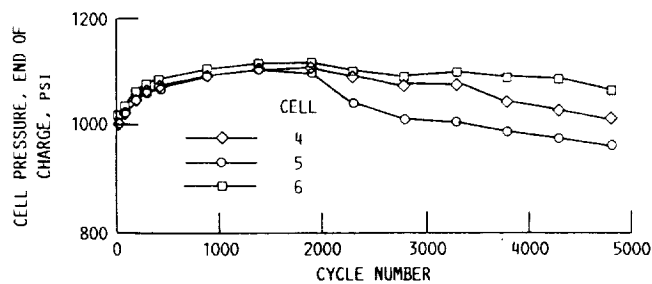


FIGURE 10. - EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED NONCATALYZED WALL WICK IPV Ni-H_2 CELLS MANUFACTURED BY EAGLE-PICHER - 26 PERCENT KOH, 60 PERCENT DOD, 10°C .

1. Report No. NASA TM-103128		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Effect of LEO Cycling on 125 Ah Advanced Design IPV Nickel-Hydrogen Battery Cells				5. Report Date	
				6. Performing Organization Code	
7. Author(s) John J. Smithrick and Stephen W. Hall				8. Performing Organization Report No. E-5458	
				10. Work Unit No. 506-41-21	
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135-3191				11. Contract or Grant No.	
				13. Type of Report and Period Covered Technical Memorandum	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546-0001				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared for the 25th Intersociety Energy Conversion Engineering Conference cosponsored by the AIChE, SAE, ACS, AIAA, ASME, and IEEE, Reno, Nevada, August 12-17, 1990. John J. Smithrick, NASA Lewis Research Center. Stephen W. Hall, Naval Weapons Support Center, Crane, Indiana 47522.					
16. Abstract An advanced 125 Ah individual pressure vessel (IPV) nickel-hydrogen cell was designed. The primary function of the advanced cell, is to store and deliver energy for long-term, low-earth-orbit (LEO) spacecraft missions. The new features of this design are: (1) use of 26 percent rather than 31 percent potassium hydroxide (KOH) electrolyte, (2) use of a patented catalyzed wall wick, (3) use of serrated-edge separators to facilitate gaseous oxygen and hydrogen flow within the cell, while still maintaining physical contact with the wall wick for electrolyte management, and (4) use of a floating rather than a fixed stack (state-of-the-art) to accommodate nickel electrode expansion due to charge/discharge cycling. The significant improvements resulting from these innovations are extended cycle life; enhanced thermal, electrolyte, and oxygen management; and accommodation of nickel electrode expansion. Six 125 Ah flight cells based on this design were fabricated by Eagle-Picher. Three of the cells contain all of the advanced features (test cells) and three are the same as the test cells except they don't have catalyst on the wall wick (control cells). All six cells are in the process of being evaluated in a LEO cycle life test at the Naval Weapons Support Center, Crane, Indiana, under a NASA Lewis contract. The cells have accumulated about 4700 LEO cycles (60 percent DOD 10 °C). There have been no cell failures, the catalyzed wall wick cells however, are performing better.					
17. Key Words (Suggested by Author(s)) Aerospace batteries NiH ₂ batteries Testing of batteries			18. Distribution Statement Unclassified - Unlimited Subject Category 20		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of pages 8	
				22. Price* A02	

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio 44135

Official Business
Penalty for Private Use \$300

FOURTH CLASS MAIL

ADDRESS CORRECTION REQUESTED



Postage and Fees Paid
National Aeronautics and
Space Administration
NASA 451

NASA
